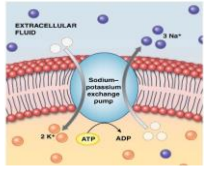
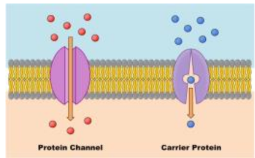
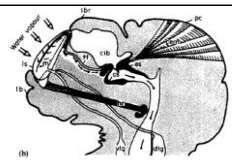
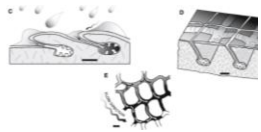
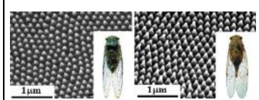
ANNEX 6

TAXONOMY OF BIOLOGICAL SEPARATION PROCESSES/MECHANISMS BY FUNCTION

Function	Active/Passive process	Processes	Biological Mechanism	Some details	Some Champions	Frequency/ "Robustness"	Pictures
Separate (filter/exchange) Ions/Molecules/gasses (including water, NaCl) Gas-Gas separation Liquid-Gas separation	**Active** Adenosine triphosphate (ATP) Electrochemical gradients	Active transport (against concentration gradient, primary and secondary) through membrane	Sodium-Potassium pump (enzime). Compartmentalization (directing molecules in dedicated vacuols).	Intra-extracellular environment. Different process depending also on Ions concentrations. Processes activated by concentration, voltage, light, mechanical stresses	Cells membrane Osmoregulator organisms (gills, kidneys) Seagulls salt glands Mangroves roots and leaves	93.5%	
	Passive Electrochemical/Concentration/hydrostratic/osmotic gradients	Passive transport through membrane: simple diffusion, facilitated diffusion, filtration, and osmosis	Ions channels (Proteins channels and proteins carriers) Osmolites compounds	Intra-extracellular environment. Different process depending also on Ions concentrations. Processes activated by concentration, voltage, light, mechanical stresses	Cells membrane Aquaporins	6.5%	

Function	Active/Passive process	Processes	Biological Mechanism	Some details	Some Champions	Frequency/ "Robustness"	Pictures
Extract moisture Gas-Gas separation	**Active** Dynamic pressure gradient (breathing) ATP **Passive:** hygroscopic compound	Phase change via structure and hygroscopic compounds	Convoluted 3D turbinates which maximize surface/volume rations and create useful turbulences. Desaturation of air passing over hygroscopic compound spread on the turbinates	In almost saturated air (75/90%)	Camel nose Elephant seal nose Saiga	66.7%	
		Phase change via hyperosmotic/hygroscopic compounds	Expose hyperosmitic/hygroscopic compounds to the external humidity to collect water	In almost saturated air (75/90%)	Cockroach mouth Tick mouth Nolama Mollis leaf	33.3%	

Function	Active/Passive process	Processes	Biological Mechanism	Some details	Some Champions	Frequency/ "Robustness"	Pictures
Attract/Repel water droplets (rain, fog, dew) Gas-Liquid separation Solid-Liquid separation Liquid-Liquid separation	**Passive** Surface energy/roughness Laplace pressure gradient	Coalescence of droplets/Hydrophilicity	Nano/micro grooves, ridges and/or hyerarchical structures on surfaces (pillars) gathering and moving fluids	Near-random array of bumps 0.5–1.5 mm apart, each about 0.5 mm in diameter. The peaks of these bumps (about 100μm in diameter) are hydrophilic, whereas the troughs are superhydrophobic by virtue of microstructure consisting of flattened hemispheres, 10 μm in diameter and arranged in a regular hexagonal array (Namibian Desert Beetle).	Namibian Beetle cuticle Desert plant in general (Cacti spines, Tillandsia leaf) Cribellate spider net	33.3%	
		Capillarity	Micro channels absorbing and moving fluids	Capillaries between 27–327 μm in width, a depth from 36 to 63 μm (Thorny devil)	Thorny devil skin, Orchids roots, Bromeliades leaf (trichomes)	12.5%	
		Hydrophobicity	Nano/micro hyerarchical structures on flat surfaces repelling and moving fluids	Ex: Cicada wing: Conical pillar: ɷ= 85 nm, S= 90 nm, h= 462 nm Pillar density 42 per 1/10000 μm2	Lotus leaf, Birds feathers, Cicada wing, Collembola cuticle	50.0%	
	Active /Passive Metabolism	Physical barrier gathering fog	Building structures intercepting fog-bearing winds Optimized exposition of fog catching fibres structures	Trenches in sand with shoulders of few millimeters high perpendicular to wind direction.(beetle) Disposition of bushes in banded patterns along the slope of the terrain to maximize interception	Flying saucer thench beetle	4.2%	

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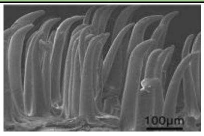
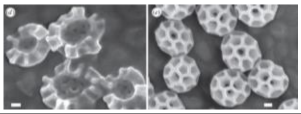
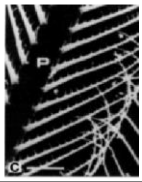
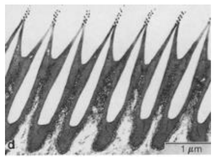
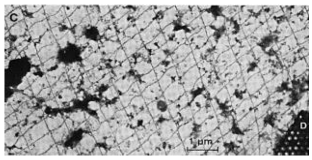
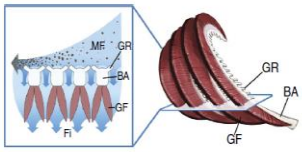
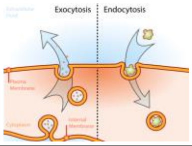
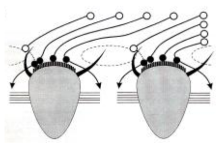
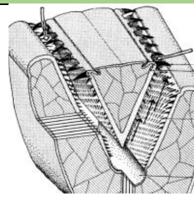
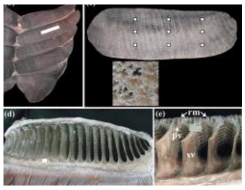
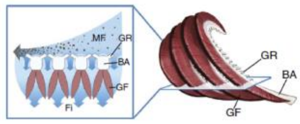
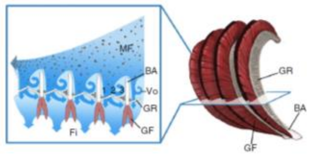
Repel apolar fluids (oil) Liquid-Liquid separation	**Passive** Surface energy/roughness	Oleophobicity in water	Nano/micro grooves, ridges and/or hyerarchical structures on flat surfaces	Shark's skin V-shaped riblets with height that varies between 200 and 500 µm, and their space varies between 100 and 300 µm Filefish hook- like spine: h= 383,7 +/- 17,6 µm ø = 51,6 +/- 5,4 µm S = 100 µm	Sharks skin, filefish scales	50.00%	
		Oleophobicity in air	Nano/microhyerarchical structures (brochomes: hexagonal hollow structure) spread on surface	Honeycomb shape texture: ø=200-700 nm + setae ø=3 µm lenght=10-30 µm	Leafhoppers wing (Cicada) Collembola	50.00%	

Function	Active/Passive process	Processes	Biological Mechanism	Some details	Some Champions	Frequency/ "Robustness"	Pictures
Separate Particles (microns) from fluids Liquid-solid separation **Reynolds number Intermediate**	**Active** pumping of water	Surface Dead-end: Sieving	2D Mesh created on demand by intertwined lamellar structures or cilia	Mesh with fixed or variable pores sizes depending on flow. Reverse flow (backflush) occurs occasionally or Pulsing flow is used to unclogg the sieve.	Atlantis menhaden (fish), Brisingid sea star, Euphausiaceans and other crustaceans feeding system	22.86%	
		Surface Dead-end: Sieving/Sorting with grooves	Sieving/sorting of particles by variable sezion grooves. Sometimes assisted by cilia	V shaped grooves with various average width (1-3 µm) and sometimes with stepped sides to select/sort and guide particles.	Porcellio Scaber, Bivalves	5.71%	
		Surface Dead end: Direct interception/ Inertial Impaction/ Diffusion/ Gravitational deposition Hydrosol filtration	Meshes (single or multiple overlayed) made with adhesive material (mucus) Also adhesive papillea	Mesh with fixed or variable pores sizes (squared/rectangular) depending on flow and particle size. Net discarded or digested with particles and reproduced. Reverse flow (backflush) occurs occasionally or Pulsing flow is used to unclogg the sieve.	Caddis fly net, Echinoderms, Gastropods, Doliolidis.	34.29%	
		Surface Dead end: Cross-flow filtration	Shapes and orientation of gill arches and rakers to concentrate particles and direct them to specific location. Often combined with other surface dead-end processes to enhance performance. Sometimes assisted by cilia movement.	Cross-flow allows Reverse flow (backflush) to occur only occasionally.	Carp fish gills, Oikopleura feeding system	8.57%	
		"Depth filtration"	Capture particles (and also lipid droplets) in layers. Incorporating them or letting them move through the layersto different location. Selective/un-selective capture of particles	Engulfed particles are directed somewhere out of the filter or digested. Use of vescicles to transport particles or variable size pores.	Human Lung's alveolar macrophage Cells membrane Echinoderms madreporite	8.57%	
		Concentration/re-direction of particles	Particles are intercepted and re-directed by ciliary movements. Cilia and cirri's sweeps create feeding vortexes that causes suspended particles to swirl into the capture zone of the following sweep.	Various orientation and movement of rows of cilia and cirri according to location of digestive system.	planktonic larvae of echinoderms, barnacles, bivalves feeding system	28.57%	

Function	Active/Passive process	Processes	Biological Mechanism	Some details	Some Champions	Frequency/ "Robustness"	Pictures
Separate Particles (mm-cm) from fluids Liquid-solid separation **Reynolds number High (maily turbulent)**	**Active** Active pumping of water Flow generated by forward movement of body	Surface Dead-end: Sieving	Use of 2D meshes, 3D strainers. Mesh created when needed by intertwined or overlaid lamellar structures on 2D or 3D. Continuous/intermittent ram filtration	Hydrodynamic pressure used to orient the filaments of the mesh and regulate porosity. Particles direction and sorting guided by turbulences through the mesh.	Duck bill, Flamingo bill, Bowhead Whale baleens	57.14%	
		Surface Dead end: Direct interception/ Inertial Impaction/ Diffusion/ Gravitational deposition Hydrosol filtration	Porous pads covered with adhesive material (mucus). Combined with cross-flow filtration Continuous/intermittent ram filtration	Filtering pads with adhesive secretion. Reverse flow (backflush) occurs occasionally to unclogg the pads.	Whale Shark gills	12.50%	
		Cross-flow filtration	Shapes and orientation of gill arches and rakers to concentrate particles and direct them to specific location Often combined with sieving to enhance performance	Cross-flow allows Reverse flow (backflush) to occur only occasionally.	Whale Shark, Basking shark, Manta ray gills, Hunbpack whale	50.00%	
		Vortical cross-step filtration	Mainstream flow interacts with the series of backward-facing steps formed by the branchial arches separated by slots where gill rakers are. The resulting vortical flow interacts with the gill rakers to concentrate particles in zones along the slot margins adjacent to the arches.	Backward-facing steps form d-type ribs which are element in which the groove aspect ratio (width of the groove between ribs divided by rib height, is less than approximately 3±4	Basking shark's gills Paddlepish's gills	25.00%	
		"Ricochet" filtration	Long, parallel arrays of leaf-like filter lobes in both wing and spoiler orientation. Flow separation occurred behind the leading edge of each filter lobe, resulting in a large, captive vortex within each pore between the lobes. Solid particles contact forces causing them to "ricochet" away from the filter pore and back into the faster-moving freestream flow.	Avoid reverse flow to unclog filter lobes.	Manta Ray gills	12.50%